ATTACHMENT 8

POTENTIAL ADVERSE CHANGES IN AGUA HEDIONDA LAGOON RESULTING FROM ABANDONMENT OF THE LAGOON INTAKE

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Introduction:

This technical memorandum analyses the potential for adverse changes in Agua Hedionda water quality, ecology, and natural resources as a result of abandoning the outer lagoon intake structure either by a no desalination project alternative or a no power plant facility operation. Adverse changes are also analyzed for a reduction in the amount of seawater pumped for a stand alone desalination project. The main emphasis of this study is the rate of beach-sand-infilling on the lagoon's ocean connection, seawater exchange and ecology due to discontinuance of dredging. The memorandum contains detailed analyses and descriptions of the potential changes of reduced seawater pumping on the lagoon's hydrodynamics circulation.

Background:

Agua Hedionda Lagoon is not a natural geomorphic formation. The current hydrological unit is approximately 54 years old. Prior to this time, Agua Hedionda was a slough comprised of shallow marsh channels filled with anaerobic hyper-saline water and flushed only briefly during winter months when high tides and rain runoff from Agua Hedionda Creek would broach the barrier berm across the lagoon inlet (Appendix 1.) This lagoon was originally built for the sole purpose of providing a retention basin to hold cooling water for the Encina Power plant. This man made lagoon is a shallow coastal embayment located within the city limits of Carlsbad, California and is wholly owned by Cabrillo Power LLC. This lagoon is bounded to the west by Carlsbad Boulevard, to the north by the city of Carlsbad, to the east by hill slopes and bluffs, and to the south by cultivated fields and the Encina Power Plant property. A railroad trestle and the Interstate 5 freeway bridge divide the lagoon into three interconnected segments; an outer segment, a middle segment, and an inner segment. At the northwest end on the Outer Lagoon, a rock jetty inlet (46 m wide and 2.7 m deep) allows free exchange of water between the ocean and the lagoon system. This inlet and the lagoon system are kept open by a routine maintenance dredging program preformed by Cabrillo Power.

The Outer Lagoon segment covers approximately 66 acres and has an averaged dredged depth of 4.6 m. This lagoon segment serves as a conveyance of cooling water from the ocean to the Encina Power Plant. Bottom sediments consist of coarser gravels and sands, in areas of higher tidal velocities and fine sands or silt/mud in lower flow areas. Much of the inter-tidal area has been lined with riprap to minimize the effects of erosion. Elsewhere, the shoreline of this segment consists primarily of fine sand with interspersed cobble patches. The Middle Lagoon is the smallest segments with a total surface area of approximately 27 acres. The bottom consists largely of clay, silt, or silty sand and a small intermittent freshwater creek drains into the northwest corner of this segment. Most of the inter-tidal zone in this segment consists of mud containing shell hash. The Inner Lagoon is the largest of the three segments with a total surface area of approximately 295 acres. The bottom sediments in this segment consist largely of finer sands, silts, clays and organic detritus especially in the far eastern lagoon section. The inter-tidal zone in this lagoon segment ranges from narrow sandy beaches to mud-clay banks except near the bridges where rip-rap has been used to stabilize the banks. Agua Hedionda Creek empties into the east end of this segment, providing intermittent freshwater infusion into the lagoon. Near the entrance of Agua Hedionda Creek are the degraded remnants of a once extensive salt marsh totaling approximately 100 acres. This former marsh now consists principally of mudflats and high marsh interspersed with salt flats and an alluvial fan.

HYDROLOGY

Circulation within the California Bight is seasonally dominated by the California Current which flows towards the southeast as an extension of the Japanese and Aleutian currents. Inshore of the California Current, the Davidson Current diverges off and forms a nearly permanent Southern California Eddy (Jones, 1971). The Davidson Current flows in a northward direction on a seasonal basis. This countercurrent tends to dominate coastal circulation patterns from September to February. Following this interval is a period of upwelling, which brings colder, nutrient rich waters into coastal environments, and leads to a period of increased biological productivity. This upwelling is typically strongest during May and June of each year as a result of northerly or northwesterly wind stresses (Dailey et. al., 1993). The combination of current and wind-induced factors leads to a general net surface circulation in inshore areas towards the southeast in the months of April, May, and June and towards the north-northwest in September, October, and December.

These general circulation patterns are sometimes disrupted by the global climatic events known as El Nino. This phenomenon results in a decrease in upwelling with resulting higher temperatures and lower biological productivity in nearshore waters. This phenomenon can occur every few years and can last from 1 to 3 years. Prolonged El Nino events can lead to dramatic changes, in the biological communities in the inshore waters of the Southern California Bight.

In the immediate vicinity of the coastline, water movements are dominated by long-shore currents, which are largely driven by prevailing winds and oceanic swell. These longshore currents typically average less than 0.1 in per sec. Oceanic swell impinging on the coast typically approach the shore from the northwest and west in winter and spring as a result of more intense Northern Hemisphere storms. In the summer and fall, oceanic swell typically approaches from the south resulting from hurricanes off the Mexican coast and Southern Hemisphere storms. Locally, wind waves typically come from the northwest and west.

Within Agua Hedionda Lagoon, circulation is dominated tidally and to a lesser extent, prevailing winds and freshwater flows from rain events. Tides exhibit a mixed semidiurnal pattern. On the flood tide, approximately 528 million gallons enter through the seaward entrance of the Outer Lagoon. Approximately half of this volume (264 million gal.) flows into the Middle and Inner lagoon segments and approximately 198 million gallons is withdrawn by the plant for cooling purposes and discharged to the ocean. The remainder (66 million gal.) remains within the outer segment. On the ebb tide, the volume of water which flowed in the middle and upper segments (264 million gal.) return through the outer segment. Approximately half of this volume (132 million gal.) leaves the lagoon to the ocean. The remainder (132 million gal.) together with the flood tide remaining within the Outer Lagoon (66 million gal.) provides the 338 million gallons need for cooling purposes by the plant during this part of the tidal cycle (EA, 1997).

Freshwater enters the lagoon from Agua Hedionda Creek, which, together with its major tributary Buena Creek, drains an 18,525 acre watershed. For most of the year flow from this watershed is minimal and the lagoon remains essentially a negative estuary (salinity gradient increases moving from the ocean to the back reaches of the lagoon) . Occasional heavy rainfall events, generally between December and April, can lead to reduced salinity in the Inner Lagoon.

PHYSICAL AND CHEMICAL WATER ENVIRONMENT

The climate in the coastal area near the Encina Power Plant is characterized as sub-tropical and semi-arid with a strong oceanic influence. The mean annual air temperature is approximately 17.2° C (63° F) with a range in monthly means from 12.7° C (55° F) to 21.6° C (71° F). Freezing temperatures are rare. Annual rainfall averages 30.5 cm (12 in.), most of which occurs in winter. The limited range in temperatures coupled with infrequent rainfall leads to a relatively stable system with respect to physical and chemical parameters in the ocean and lagoon. The physical and chemical characteristics of lagoon waters are similar to that of the ocean and only slightly modified as a result of lagoon specific influences (depth, freshwater runoff, oxygen production and consumtion). Lagoon physical parameters are discussed below.

Water Temperature:

Water temperatures in the lagoon exhibit a typical seasonal pattern reflecting the substantial tidal exchange with the Pacific Ocean and the effects of solar warming of the water while in the relatively shallow lagoon system. Temperatures in the Outer Lagoon generally range from 58 ° F during winter to more than 70 ° F during summer. This limited temperature range reflects the relatively stable climatic conditions in Southern California. Temperatures in the Outer Lagoon were typically 1-4 ° C higher than water temperatures in the ocean at the same time (SDG&E 1980). In shallow areas, especially in the Inner Lagoon, water temperatures are often several degrees higher than in the Outer Lagoon as a result of solar heating.

Salinity:

Salinity in the lagoon are generally similar to that of the adjacent ocean as there is a high degree of mixing and relatively little fresh water input for dilution. Salinity exhibit little seasonal pattern and typically range between 30 and 34 ppt. In the Outer Lagoon, Salinity tends to be almost identical to that of the ocean whereas greater differences between the ocean and the Inner Lagoon are more typical. During dry periods, evaporation in the Inner Lagoon can result in slightly elevated Salinity (1 -2 ppt) compared to the ocean whereas during periods of high runoff from Agua Hedionda Creek, Salinity in this segment can be reduced below that of the ocean through dilution with freshwater.

Dissolved Oxygen:

Dissolved oxygen levels within the lagoon are more variable than that of the adjacent ocean waters. Primary production during the day by phytoplankton, eel grass, and macroalgae tends to increase dissolved oxygen levels over that of the incoming ocean waters. On the other hand, respiration by plants (at night), bacteria, and animals, in both the water column and sediments, together with the natural oxidation of organic compounds, tend to reduce dissolved oxygen levels. As a result, dissolved oxygen concentrations within the lagoon can vary considerably depending upon location, both horizontally and vertically, and time of day. In the Outer Lagoon and in the larger channels, tidal mixing tends to produce uniformity, both horizontally and vertically. In areas with more limited tidal mixing, dissolved oxygen levels near the bottom tend to be much lower than at the surface.

Biological Baseline:

Since the present day hydrological unit of Aqua Hedionda Lagoon is only 54 year old and never existed in a natural state with no anthropogenic effects, it is a subjective task to establish a biological baseline for this lagoon. One could establish the baseline condition as the hyper-saline slough which existed prior to the lagoon being built and contained no marine or estuarine value. Another approach for establishing the biological baseline would be to evaluate the conditions at the time that the lagoon was finished and the circulating pumps for the power plant were turned on. At this point, no biological habitats had a chance to foam. There were no eelgrass meadows, no algal mats to provide nursery grounds for fish, and benthic invertebrates had not yet been established. Lastly, the biological baseline could be based at sometime during the power plants operation that despite the continued use of the lagoon water (at consumption rates has high as 860 mgd) the biological community became established. This community has varied throughout the 54 years of the lagoon's existence as a result of periods of high rainfall, severity of Red Tide events, and other natural and anthropogenic effects. Regardless of the timeframe that one chooses to establish the biological baseline, the timeframe that represents the greatest benefits to the marine environment in terms of providing eelgrass meadows, nursery habitat, juvenile rearing habitat, and marine bird foraging habitat is during the power plant existence and the resulting continued maintenance, i.e. dredging, of the lagoon. It should also be noted that the lagoon structure and the habitat that it provides for the marine biological community would fail if dredging were to cease. This point is further explored in section "Lagoon closure and the effects of dredging".

Biological Assessment:

Lagoon Habitats.

The biological communities of Agua Hedionda contain a terrestrial, marsh/inter-tidal and Sub tidal component. The primary terrestrial component is the upland community located at the east end of the inner lagoon. The marsh community contain a both a terrestrial and inter-tidal component and within this lagoon serves as the transition zone between the back reaches of the inner lagoon and the upland community. The inter-tidal community is the zone around the lagoon between the tidal range exhibited within the lagoon. Inter-tidal acreage is approximately 108 acres for the lagoon as a whole. The ratio between inter-tidal and sub-tidal habitats varies as sedimentation increases in the lagoon. Prior to a dredge event in which a well defined inlet sand bar has formed, the tidal ranged is reduced throughout the lagoon which has an effect of reducing the inter-tidal habitat by 33 acres to a total of 75 acres. This is a result of increase tidal lag time cause by the sub-tidal ground friction. The largest biological community is the Sub tidal component and contains rock, sand, mud, and eelgrass habitats. Arial extent of these habitats has remained relatively consistent through the 54 years of the lagoons existence with the exception of the acreage of eelgrass and the sand/mud habitats (MEC, 1994).

Most of the bottom is covered by a relatively firm sand-silt mixture with silt being predominant in relatively quiescent areas while sand predominates in areas of higher current velocities. Extensive eelgrass (*Zostera marina*) beds can be found throughout the shallower areas of the lagoon while sargassum (*Sargassum muticum*) is common along the shores of the Outer Lagoon nearest the inlet. In the Inner and Middle lagoons, the shoreline consists largely of fine sand with cobble patches whereas the Outer Lagoon is principally lined with rip-rap to prevent erosion.

The major sub-tidal habitats of the lagoon and examples of the types of species residing in those habitats are presented below:

Eelgrass –Currently, at 8.05 acres, the middle lagoon contains the largest area of eelgrass (Table 1). However, in the past the inner lagoon contained the majority of eelgrass habitat. This habitat is an important nursery ground of many offshore fishes and juvenile lobster (*Panulirus interruptus*). Resident fish include Spotted Bay Bass (*Paralabrax clathratus*) Barred Sand Bass (*Paralabrax nebulifer*), Kelp bass (*Paralabrax clathratus*), and several species of Perch and Crocker and also contains a high density of benthic invertebrates.

Rock – 2.06 acres of rocky habitat is found within the lagoon. The majority of this habitat is located in the outer lagoon with smaller amounts found in the inner and middle lagoon around the banks that lead up to interstate 5 and the railroad tracks. The rocky habitat is composed mainly of rip rap areas that were placed along the shoreline were the surrounding terrestrial area slopes toward the lagoon. The majority of this habitat is found in the outer Lagoon and is an important nursery ground of many offshore fishes and juvenile lobster and other benthic invertebrates. Resident fish include Spotted Bay Bass (*Paralabrax clathratus*) Barred Sand Bass (*Paralabrax nebulifer*), Kelp bass (*Paralabrax clathratus*), Garibaldi (*Hypsypops rubicundus*), several species of Perch and Crocker. Invertebrates include the Spiny Lobster (*Panulirus interruptus*), Two Spotted Octopus (*Octopus bimaculatus*) and Purple Sea Urchin (*Strongylocentrotus purpuratus*)

Sand/Mud – The Majority of the Lagoon bottom is comprised of Sand, Sand/Mud, or silt. The distribution of this habitat between the three segments of the lagoon is directly correlated with the size of each segment. The inner lagoonResidents of this habitat include California Halibut (*Paralichthys californicus*), Spotted Bay Bass (*Paralabrax clathratus*) Barred Sand Bass (*Paralabrax nebulifer*), several species of Perch and Crocker.

Table 1. Location and acreage of <u>sub-tidal</u> lagoon habitats

Habitat	Location	Acreage	Date	Lit Source
Eelgrass	Outer	6.32	Dec, 2006	Merkel, 2006
	Middle	8.05	Dec, 2006	Merkel, 2006
	Inner	1.5	Jan, 2007	Verbal Merkel
Rock	Outer	1.28	Jan, 2007	Le Page Per. Data
	Middle	0.62	Jan, 2007	Le Page Per. Data
	Inner	0.16	Jan, 2007	Le Page Per. Data
Sand/Mud	Outer	41.4	Jan, 2007	Le Page Per. Data
	Middle	10.67	Jan, 2007	Le Page Per. Data
	Inner	174.34	Jan, 2007	Le Page Per. Data
Marsh	Outer	0	1993	MEC, 1993
	Middle	0	1993	MEC, 1993
	Inner	17	1993	MEC, 1993
UpLand	Outer	0	1993	MEC, 1993
	Middle	0	1993	MEC, 1993
	Inner	75	1993	MEC, 1993

In addition to its year-round inhabitants, the lagoon serves as important spawning and/or nursery habitat for a variety of marine species that make seasonal migrations into the lagoon. Supplementing these year-round and seasonal inhabitants are species that wander into the lagoon or are transported in by tidal currents. The relatively protected shallow, warmer waters of the lagoon coupled with the variety of species leads to a greater biological productivity than found in adjacent coastal waters.

Benthic Invertebrates. Previous studies have documented at least 182 distinct taxa of benthic macro invertebrates inhabiting Agua Hedionda Lagoon (SDG&E 1980). This list includes both infaunal and epibenthic species, all common to shallow water habitats of Southern California. The distribution and relative abundance of these species within the lagoon is primarily determined by sediment characteristics (Bradshaw et al. 1976).

Phytoplankton. Phytoplankton, consisting primarily of diatoms and dinoflagellates, provide important primary production to the Agua Hedionda Lagoon ecosystem (Bradshaw et al. 1976). Many of the diatoms common in the lagoon are benthic and not truly part of the plankton community. Microzooplankton in the lagoon consists of smaller zooplankton (e.g., rotifers) as well as larval stages of larger macrozooplankton and benthic invertebrates (Bradshaw et al. 1976). The macrozooplankton community within the lagoon is dominated by copepods, especially *Acartia clausii*, *Euterpina acutifrons*, and *Oithona oculata* (Bradshaw et al. 1976). The overall species composition and abundance of this community, according to Bradshaw, was generally similar to that of other shallow coastal habitats of Southern California.

Fish. A total of 104 species of fish have been reported as juveniles or adults from the Agua Hedionda Lagoon (SDG&E, 1980). A total of 68 species were collected by nekton sampling in the lagoon. These catches were dominated by topsmelt, deepbody anchovy and slough anchovy, which together comprised more than 77 percent of the catch. Catch was highest in the Inner Lagoon where a total of 40 species were collected. In this area of the lagoon, the same three dominant species accounted for more than 86 percent of the overall catch. In the Middle Lagoon, overall catch was intermediate with a total of 40 species being collected. Three species, topsmelt, shiner surfperch and California grunion together comprised more than 81 percent of the catch. In the Outer Lagoon, overall catches were lowest with 39 -species being collected. Four species, topsmelt, California grunion, walleye surfperch, and California halibut comprised more than 77 percent of the catch. Prior studies found a total of 88 species of fish were collected in impingement sampling including 36 species of fish not collected in nekton sampling of the lagoon. These additional species were typically marine species rarely encountered in the lagoon (E.A., 1997). Five species of fish, deepbody anchovy, topsmelt, northern anchovy, queenfish, and shiner perch, individually comprised more than 10 percent of the catch and together comprised more than 72 percent of the overall impingement collections. Current impingement data recorded 98 species (Table 2) which compares well with the E.A., 1997 study. In addition to the juvenile and adult fish, a total of 36 species of fish were also collected as eggs and larvae in plankton sampling within the lagoon. All of these species were also collected as juveniles or adults within the lagoon. Overall, egg collections were dominated by anchovies, drums, and sanddabs while larval collections were dominated by silversides, gobies, and anchovies.

Table 2. Fishes, sharks, and rays observed in Agua Hedionda from June 2004 to June 2005.

(unpublished data)

Acanthogobius flavimanus	Yellowfin goby
Albula vulpes	Bonefish
Ameiurus natalis	Yellow bullhead
Ameiurus nebulosus	Brown bullhead
Amphistichus argenteus	Barred surfperch
Anchoa compressa	Deepbody anchovy
Anchoa delicatissima	Slough anchovy
Anchoa spp.	Anchovy
Anisotremus davidsoni	Sargo
Atherinops affinis	Topsmelt
Atherinopsis californiensis	Jacksmelt
Atractoscion nobilis	White seabass
Brachyistius frenatus	Kelp surfperch
Cheilopogon pinnatibarbatus	Smallhead flyingfish
Cheilotrema saturnum	Black croaker
Chromis punctipinnis	Blacksmith
Citharichthys sordidus	Pacific sanddab
Citharichthys spp.	Sanddabs
Citharichthys stigmaeus	Speckled sanddab
Cymatogaster aggregata	Shiner surfperch
Cynoscion parvipinnis	Shortfin corvina
Dasyatis dipterura	Diamond stingray
Dorosoma petenense	Threadfin shad
Embiotoca jacksoni	Black surfperch
Engraulis mordax	Northern anchovy
Fundulus parvipinnis	California killifish
Genyonemus lineatus	White croaker
Gibbonsia montereyensis	Crevice kelpfish
Gillichthys mirabilis	Longjaw mudsucker
Girella nigricans	Opaleye
Gymnura marmorata	Calif. butterfly ray
Halichoeres semicinctus	Rock wrasse
Hermosilla azurea	Zebra perch
Heterodontus francisci	Horn shark
Heterostichus rostratus	Giant kelpfish
Heterostichus spp.	Kelpfish
Hyperprosopon argenteum	Walleye surfperch
Hyperprosopon spp.	Surfperch
Hyporhamphus rosae	California halfbeak
Hypsoblennius gentilis	Bay blenny
Hypsoblennius gilberti	Rockpool blenny
Hypsoblennius jenkinsi	Mussel blenny
Hypsoblennius spp.	Blennies
Hypsypops rubicundus	Garibaldi
Lepomis cyanellus	Green sunfish
Leptocottus armatus	Pacific staghorn sculpin
Leuresthes tenuis	California grunion
Lyopsetta exilis	Slender sole
Mugil cephalus	Striped mullet
Mustelus californicus	Gray smoothhound
Myliobatis californica	Bat ray
Ophichthus zophochir	Yellow snake eel
Oxylebius pictus	Painted greenling
Paraclinus integripinnis	Reef finspot
Paralabrax clathratus	Kelp bass
Paralabrax maculatofasciatus	Spotted sand bass
Paralabrax nebulifer	Barred sand bass
Paralichthys californicus	California halibut
Peprilus simillimus	Pacific butterfish
Phanerodon furcatus	White surfperch
Platyrhinoidis triseriata	Thornback
Pleuronectiformes unid.	Flatfishes
Pleuronichthys guttulatus	Diamond turbot
Pleuronichthys ritteri	Spotted turbot
Pleuronichthys verticalis	Hornyhead turbot
Porichthys myriaster	Specklefin midshipman
Porichthys notatus	Plainfin midshipman
Porichthys spp.	Midshipman
Pylodictis olivaris	Flathead catfish
Rhacochilus vacca	Pile surfperch
Rhinobatos productus	Shovelnose guitarfish
Roncador stearnsi	Spotfin croaker
Sarda chiliensis	Pacific bonito
Sardinops sagax	Pacific sardine
Sciaenidae unid.	Croaker
Scomber japonicus	Pacific mackerel
Scorpaena guttata	Calif. scorpionfish
Scorpaenidae	Scorpionfishes
Sebastes atrovirens	Kelp rockfish
Seriola lalandi	Yellowtail jack
Seriphus politus	Queenfish
Sphyraena argentea	California barracuda
Strongylura exilis	California needlefish
Symphurus atricauda	California tonguefish
Syngnathus leptorhynchus	Bay pipefish
Syngnathus spp.	Pipefishes
Tilapia spp.	Tilapias
Torpedo californica	Pacific electric ray
Trachurus symmetricus	Jack mackerel
Triakis semifasciata	Leopard shark
Umbrina roncador	Yellowfin croaker
Urolophus halleri	Round stingray
Xenistius californiensis	Salema
Zoarcidae	Eelpouts

Medialuna californiensis	Halfmoon		
Menticirrhus undulatus	California corbina		
Micrometrus minimus	Dwarf surfperch		

Birds: Agua Hedionda Lagoon provides habitat for migratory birds as well as resident bird populations (Table 3). Some of the migratory birds use the lagoon as a resting point prior to their nesting area to the south, while others such as the California Least Tern (*Sterna antillarum browni*) use the lagoon as a nesting site (MEC, 1995). Of the 76 species of birds observed within the lagoon area the majority of them are water associated birds (Accounting for 75% of the total number of species.) Within this group of birds, the diversity of shore birds was the highest followed by ducks, geese and coots. Agua Hedionda Lagoon contains bird populations of several special status species, which consist of the California Brown Pelican (*Pelecanus occidentalis californica*), California Least Tern (*Sterna antillarum browni*), Western Snowy Plover (*Charadrius atexandrinus nivosus*), Belding's Savannah Sparrow (*Passerculus sandwichensis beldingi*), and the California gnatcatcher (*Polioptila californica*).

Table 3. Birds observed 1994-1995 (MEC, 1997)

American Avocel	Recurvirostra americana	Lesser Scaup	Aythya affinis
American Coot	Fulica americana	Lincoln's Sparrow	Melospiia lincolnii
American Crow	Corvus brachyrltynchos	Loggerhead Shrike	Lanius ludovicianus
American Wigeon	Anas americana	Long-billed Curlew	Numenius americanus
Anna's Hummingbird	Calypte anna	Mallard	Anas platyrhynchos
Barn Swallow	Hirundo ruslica	Marbled Godwit	Limosafcdoa
Belding's Savannah Sparrow	Passerculus sandwichensis beldingi	Marsh Wren	Cistothorus palustris
Black Phoebe	Sayomis nigricans	Mourning Dove	Zenaida macroura
Black Skimmer	Rhynchops niger	Northern Harrier	Circus cyaneus
Black-bellied Plover	Pluvialis squatarola	Northern Pintail	Anas acula
Black-necked Stilt	Himanlopui mexicanus	Northern Rough-winged Swallow	Stelgidopteryx serripennis
Bonaparte's Gull	Larus Philadelphia	Northern Shoveler	Anas clypcata
Bufflehead	Bucephala albeola	Osprey	Pandion haliaelus
California Brown Pelican	Pelecanus occidentalis californica	Pied-billed Grebe	Podilymbus podiceps
California Gull	Larus californicus	Red-breasled Merganser	Mergus senator
California Least Tern	Sterna antillarum browni	Red-necked Phalarope	Phalaropus lobalus
Canvasback	Aylhya valisineria	Red-tailed Hawk	Buteo jamaicensis
Caspian Tern	Sterna caspia	Red- winged Blackbird	Agelaius phoeniceus
Cinnamon Teal	Anas cyanoptera	Redhead	Aylhya americana
Clark's Grebe	Aechmophorus clarkii	Ring-billed Gull	Larus delawarensis
Cliff Swallow	Hirundo pyrrhonola	Ruddy Duck	Oxyura jamaicensis

Common Raven	Corvus corax	Sanderling	Calidris alba
Common Snipe	Gallinago gallinago	Sandpiper, unidentified	Calidris spp.
Common Yellowthroal	Geolhlypis irichas	Savannah Sparrow	Passerculus sandwichensis
Cooper's Hawk	Accipiter cooperii	Scaup spp.	Athya spp.
Double-crested Cormorant	Phalacrocorax auritus	Semipalmated Plover	Charadrius semipaimatus
Dowitcher spp.	Limnodromus spp.	Short-billed Dowitcher	Umnodromus griseus
Dunlin	Calidris alpina	Snowy Egret	Egretta thula
Eared Grebe	Podiceps nigricollis	Song Sparrow	Melospim melodia
Forster's Tem	Sterna forsteri	Turkey Vulture	Cathartes aura
Gadwall	Anas strepera	Western Grebe	Aechmophorus occidentalis
Great Blue Heron	Ardea herodias	Western Gull	Larus occidentalis
Great Egret	Casmerodius albus	Western Mendowlark	Slumella neglecfa
Greater Yellowlegs	Tringa melanoleuca	Western Sandpiper	Calidris mauri
Green-winged Teal	Anas crecca	Western Snowy Plover	Charadrius atexandrinus nivosus
Homed Grebe	Podiceps auritus	Whinibrel	Numenius phaeopus
House Finch	Carpodacus mexicanus	Willet	Catoplrophorus semipaimatus
Killdeer	Charadrius vociferus		
Least Sandpiper	Calidris mintititla		

Eelgrass-*Zostera marina*. Eelgrass is a flowering marine plant Agua Hedionda at depths between 0.0 feet Mean Lower Low Water (MLLW) and -10 feet (MLLW). Eelgrass is considered a sensitive marine resource in southern California because eelgrass meadows provide cover and habitat for many types of marine organisms.

Eelgrass canopy (consisting of shoots and leaves approximately two to three feet long) attract many marine invertebrates and fishes and the added vegetation and the vertical relief it provides enhances the abundance and the diversity of the marine life compared to areas where the sediments are barren. The vegetation also serves a nursery function for many juvenile fishes, including species of commercial and/or sportsfish value (California halibut and barred sand bass). A diverse community of bottom-dwelling invertebrates (i.e., clams, crabs, and worms) live within the soft sediments that cover the root and rhizome mass system.

Eelgrass meadows are also critical foraging centers for seabirds (such as the endangered California least tern) that seek out baitfish (i.e., juvenile topsmelt) attracted to the eelgrass cover. Lastly, eelgrass is an important contributor to the detrital (decaying organic) food web of bays as the decaying plant material is consumed by many benthic invertebrates (such as polychaete worms) and reduced to primary nutrients by bacteria.

A review of the literature pertaining to eelgrass coverage shows that the greatest coverage of eelgrass was recorded during a survey completed in 1976 which reported 70 acres of eelgrass (Bradshaw et. al. 1976). Currently it is estimated that only 15.42 acres are present. Personal observations and conversations with Merkel and Assoc. have lead to a conclusion that despite a recent eelgrass mitigation transplant of over 14 acres in the inter lagoon alone, the heavy rains of 2005 and the severe red tide event during the following summer killed off large portions of eelgrass within the lagoon.

Lagoon closure and the effects of dredging

The following paragraph is a partial summary of the attached document entitled "Coastal processes effects of reduced intake flows at Agua Hedionda Lagoon" (Jenkins, 2007).

Agua Hedionda Lagoon is located within the Oceanside Littoral Cell. Within this cell, sand move from the north to south and eventually lost out of the cell at the extreme southern edge as a result of two submarine canyons that transport the sand to deep ocean basins. Sand is also lost from the cell by tidal action into and out of the lagoon which will trap sand into the lagoon regardless of the flow rate at the intake structure. The trapped sand has several impacts on both the lagoon and the littoral cell. These impacts include among others the depleting of sand beaches that are located south of the lagoon and the creation of sand bars within the lagoon. These sand bars if not removed by maintenance dredging will reduce tidal exchange rates and lagoon water resident time which deplete nutrients and oxygen levels within the lagoon. The sand bars over time will grow to a point were inlet closure can occur resulting in a chocking off the lagoon and the destruction of the marine habitat. The rate at which this occurs is dependent on many factors including natural factors such as winter storms and El Nino events and also anthropogenic factors such as beach replenishment projects to the north of the lagoon and the rate of water uptake in the outer lagoon for cooling water purposes. The rate at which sand influx occurs has been monitored continually. During normal plant operations, which requires the use of an average daily volume of water at a rate of 528.69 mgd the lagoon entrains 184,724 cubic yards of sand per year. This volume of sand increases the risk of lagoon closure by 11% per year. Within 4.5 years after maintenance dredging the risk is high enough to assume that closure is more probable then not (Table 4). A reduced flow scenario capable of supporting the proposed desalination project on stand alone bases would decrease the sand influx to 106,218 cubic yards per year, thus increasing the time of likely lagoon closure to 7.9 years. Under a no water intake scenario the risk of lagoon closure is more likely then not after 8.2 years

Table 4. Relationship between power plant flow rate, sand influx, and threat of lagoon closure.

Lagoon State	Avg. Volume of Water needed (mgd)	Rate of Sand Influx per year (yds^3)	Time of likely Lagoon Closure (years)	Dredge Cycle (years)
Power Plant Normal Op.	529	184,724	4.5	2-3
Stand alone Desalination	304	106,218	7.9	4-5
No flow	0	90,000	8.2	4-5

Under normal power plant operations the maintenance dredging interval has been fairly consistent at every two to three years for several reasons. The two most important are: 1) Sand removal must take place prior to a point where there is still enough leeway in time so that a sudden lagoon closure is not probable; 2) Sand removal must take place at a point prior to the lagoon hydrology being compromised. For a reduced flow (stand alone desalination plant) and a "No Flow" scenario necessary dredge intervals would be the same and should be done every four to five years. As such, there would be no difference in the potential impacts to the lagoon and beach habitats under a reduced flow or no flow scenario.

Other alternatives to prolong dredging activities were evaluated by Cabrillo Power in the year 2001. During the course of this investigation, it was decided that sand infilling could be reduced if the north end of the entrance jetty was extended 200 feet seaward. The analysis indicated that the extension of the jetty would decrease the rate of infilling, but the lagoon would still need a maintenance dredging program. The application for permits to extend the jetty was ultimately withdrawn since the lead agency, State Lands Commission identified concerns about the potential for sand bypassing the lagoon and covering adjacent hard bottom habitat including the sensitive surfgrass habitat and decided that an intake pipe offshore was a better alternative to provide cooling water for the power plant. Cabrillo Power found this alternative was not acceptable due to likely significant impacts to hard bottom habitats that are offshore and because it would not solve the problem of sand infilling into the lagoon. Furthermore, concerns about additional sands entering into the littoral zone north of the jetty as a result of beach nourishment projects did not materialize. In light of these hurdles it was determined that impacts associated with both the extension of the lagoon jetty and the offshore intake were unacceptable and neither approach would create a situation were dredging would no longer be needed.

Value of Maintenance Dredging:

The benefits of dredging to maintain the hydrological unit of Agua Hedionda include preserving the habitats necessary to maintain the current biological community, providing and maintaining aquaculture endeavors, recreational activities, and providing the necessary volume to maintain the tidal prism to provide the power plant water for cooling purposes. Thus being in conformity with the California Ocean Plan which identifies beneficial uses of the ocean waters of the State as to be as follows: Industrial water supply; water contact and non-contact recreation, including aesthetic enjoyment; navigation, commercial and sport fishing; mariculture; preservation and enhancement of designated Areas of Special Biological Significance; rare and endangered species; marine habitat; fish spawning and shellfish harvesting. Continued maintenance dredging will insure that these beneficial uses will not be lost and will protected and be consisted with policies of Chapter 3 of the Coastal Act 30220, 30230, 30231, and 30233. These benefits far outweigh the alternative of no dredging and losing 388 acres of highly productive marine habitat as a result of beach infilling and the closing off of the lagoon inlet. It is this mind set that the Coastal Commission has used in approving current and past dredge permits. As stated in the California Costal Commission's staff report and approval notice for the recently approved dredge permit for Cabrillo Power (Application # 6-06-61) the proposed dredging is "consistent with past Commission actions for maintenance dredging and beach deposition". The resolution on this application was that an approval was granted on the grounds that it is in conformity with policies of Chapter 3 of the Coastal Act. It should be noted that the failure to dredge the lagoon would be contrary to this coastal act. It would violate Section 30230 by failing to maintain and enhance marine resources; it violate Section 30231 by failing to protect the biological productivity and the quality of coastal waters, wetlands and estuaries; and Section 30233 and 30220 by limiting the ability of water oriented recreational activities and aquaculture endeavors. This approved permit and the protocol submitted with the dredge application is nearly identical to prior application and has been shown to adequately deal with the maintenance dredging required to maintain the hydrology of the lagoon. Therefore, any future dredging that would be required under a reduced flow scenario for a stand alone desalination plant would remain the same. This dredge protocol provides for the protection of sensitive marine resources, in particular eel grass beds.

Users of Agua Hedionda Lagoon

The Agua Hedionda Lagoon (AHL) was initially dredged in 1952 resulting in numerous opportunities for public access and recreation in and around the lagoon. Since then, several enterprises have been built along the lagoon shores to take advantage of the ecosystem created by the cooling water flow and dredging operations. The lagoon supports both profit and non-profit enterprises. Private businesses along the AHL include the Carlsbad Aquafarm and California Watersports. Non-profit groups include the Hubbs-SeaWorld Research Institute (HSWRI), which runs a state-of-the-art fish hatchery along the lagoon shores. In addition, the YMCA and the Agua Hedionda Lagoon Foundation (AHLF) support recreational and educational activities at the lagoon. These enterprises consider the AHL a unique and invaluable resource, which they have become dependant for their operations.

FOR PROFIT ENTERPRISES

Carlsbad Aquafarm

The Carlsbad Aquafarm leases 6 acres of the outer AHL and uses the environment created by Encina Power Station (EPS) to grow mussels, oysters and scallops. Annual harvest averages one million pound of shellfish a year. The business started in 1990 and has expanded to include land-based aquaculture for seaweed, abalone and seahorses. The aquafarm supplies restaurants in Los Angeles, Orange, and San Diego counties and has customers in both the east coast and mid-western United States. In addition, the business has developed an international customer base, providing shellfish and algae for research.

Along with providing a commercial and academic benefit to the community their endeavors also lessen the pressure on the natural stocks and the habitats that they live in.

The aquaculture farm is dependant upon the current environmental conditions of the Agua Hedionda Lagoon. The cooling water flow allow the aquafarm necessary conditions to grow high quality shellfish. The water quality is very important for the growth of the shellfish and for ensuring they are acceptable for human consumption. If dredging of the lagoon was to decrease or ultimately cease, the conditions the aquafarm needs to grow its products would quickly deteriorate and the farm would no longer be able to grow shellfish and the business would have to close.

The Agua Hedionda Lagoon ecosystem is a unique ecosystem for aquaculture farming. It is considered the only location in southern California where the Carlsbad Aquafarm can grow mussels, oysters, and scallops. All other locations do not have the proper designation by the Department of Health Services to allow for such an endeavor.

California Watersports

California Watersports is located at the Snug Harbor Marina, in the inner lagoon of the AHL.

The watersports facility is dependant upon the current conditions of the AHL. The tidal flushing allows for clean water, which attracts people to the lagoon. They also require significant water depth to allow for the operation of the water craft. If dredging of the lagoon was stopped, this business and all lagoon related recreation would cease.

NON-PROFIT ENTERPRISES

Hubbs-SeaWorld Research Institute

The Hubbs-SeaWorld Research Institute built the Leon Raymond Hubbard, Jr. Marine Fish Hatchery along the shoreline of the outer AHL in 1995. It is the only commercial-scale marine finfish hatchery in the west coast of the United States. This facility is part of the Ocean Resources Enhancement and Hatchery Program, focusing on the rearing white seabass (*Atractoscion nobilis*) for introduction into the wild. The facility can produce up to 350,000 juvenile white seabass annually. Annual fish released per year varies, in 2004 over 270,000 fish were released and in 2005, about 100,000 fish were released. In addition to white seabass, hatchery staff also researches the rearing of other species such as California sheepshead (*Semicossyphus pulcher*) and California yellowtail (*Seriola dorsalis*).

The intake of the hatchery is located in the AHL and requires high quality ocean water supported by maintenance dreding of the lagoon. If dredging of the lagoon were to stop, the intake would have to be relocated, which is not feasible for the non-profit organization.

The AHL was an ideal location for the HSWRI to build this state of the art hatchery. The fish produced by the hatchery are highly valuable to the fishing community. White seabass populations were in significant decline due to overfishing and habitat destruction. The Leon Raymond Hubbard, Jr. Marine Fish Hatchery is the only facility rearing this species. To date, the facility has released over 1,000,000 white seabass into the wild and catch rates by fishermen are increasing, suggesting that the population may be on the rise. Each fish is valued about $10 in terms of food and human labor costs (Rodgers, 2006). If the hatchery has the capability to release 350,000 fish each year, this equates to a potential value of $3,500,000 for the hatchery operations at the AHL.

YMCA

The YMCA leases land on the middle lagoon area of the AHL where they hold a summer camp for children ages 6-12 years old. Recreational activities conducted at the camp include swimming and boating. The camp runs for about 6 weeks with about 60 kids/ week. They also offer their facilities for other recreational uses in the summer.

YMCA personnel monitor the water quality of the AHL where the camp is located. Since the area is used for swimming, the water quality standards must be closely monitored. At present, the cooling water intake and tidal flushing help maintain a safe water quality level for swimming. If the cooling water intake from EPS and dredging activities were to stop, water quality levels would likely drop below acceptable standards for swimming.

The YMCA chose to hold the camp along the shores of the AHL because of the area's appeal to the public. The lagoon offers a safe calm environment, ideal for a children's swim camp. A value for recreational swimming cannot easily be assigned. The camp can accommodate up to 360 children per summer session and offers their facilities for other uses. There are no other locations in the Carlsbad area that offer uncrowded safe conditions where children are able to swim like to AHL. Thus, the area is considered invaluable in terms of offering a unique location for children's recreation.

Agua Hedionda Lagoon Foundation

The Agua Hedionda Lagoon Foundation (AHLF) is a non-profit organization founded in 1990 located along the outer lagoon shores. The foundation was established "to conserve, restore, and enhance environmental features of the AHL and its watershed."[1] Currently the foundation has 250 members.

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[1] http://www.aguahedionda.org/AHLFhomepage3.htm

The AHLF has several goals to promote environmental awareness and recreation at the lagoon. Currently they offer a couple of miles of hiking trails but would like to extend the trails to cover the circumference of the lagoon. In addition, they would like to develop pilot school programs educating children about lagoon ecology and indigenous cultures. They would like to install webcams along the lagoon shores so that people from all over the world can learn about the lagoon. The foundation recently completed a Discovery Center on the lagoon shore to provide a center of wetland-related environmental education for the community.

The value of the lagoon as a site for recreation and environmental education depends considerably on the water quality of the lagoon. The lagoon attracts hundreds of species of birds, mammals, fish, invertebrates, and plants (AHLF 2005). These animals in turn, attract people who will use of the area for hiking, fishing, birding, and for teaching their children about the environment and indigenous cultures. If the water quality of the lagoon were to decrease, wildlife populations could decrease and fewer people would be attracted to the area for recreation and education.

The AHLF considers the AHL as the only wetland south of Morro Bay where people can actually touch and get in the water. The foundation believes that the area holds a strong potential as a site of recreation and environmental education to not only Carlsbad, but to the world. A monetary value cannot easily be placed on the recreational and educational activities sponsored by the AHLF. However the uniqueness of the lagoon and the area available for recreational potential (approximately 400 acres) makes it a highly valuable resource in southern California.

Conclusions:

Agua Hedionda Lagoon is a man made hydrological unit that is 54 years old. Prior to the dredging of this lagoon it was a hyper-saline slough that had no marine component a thus provide little if any benefits to the surrounding nearshore environment. Within the 54 years of its existence and despite the fact that the Encina Power Plant uses up to 680 mgd for their cooling water needs the lagoon has and continues to perform as a marine, estuarine, and wetland biological unit. It provides nursery grounds and habitat for several fish, invertebrates, and avian species including some of which that are listed as sensitive species.

The local community also benefits from this lagoon. The various uses of the lagoon (commercial, research, recreational) make the area an important resource. A monetary value of over $8,500,000 could potentially be generated from the enterprises discussed above. Recreational activities cannot easily be assigned a direct monetary value. However, in place of a monetary value, issues such as the size and quality of the area, accessibility to the public, and the uniqueness may be considered (Letson and Milan, 2002). The city of Carlsbad maintains strong control over boat use of the AHL, as users are required to obtain permits for both active and passive vessels used on the lagoon. Currently the city issues about 400 permits per year, with a 50-50% proportion between active and passive permits. As stated above, the AHLF has over 200 members. In addition, recreational fishing is a popular pastime along the outer lagoon shore. The site is considered heavily used by the California Department of Fish and Game. CA DFG data on fishing pressure for the Carlsbad area shows that the AHL attracted 79% of the recreational fishing effort compared to other observed locations (Oceanside Jetty to Batiquitos Lagoon, 18%; Encinitas to Leucadia, 3%) from 2004-2005 (N=542); Michelle Horeczko, California Department of Fish and Game, pers. comm.). The AHL has strong appeal for recreation given the number of permits issued and the number of recreational anglers that use the lagoon.

The lagoon offers a large area for both aquatic and land based recreation and could be considered as high quality given the amount of wildlife that is found there as well as the number of people that use the area. Each enterprise along the lagoon views the area as unique; they would not be able to run their businesses or facilities elsewhere. If the exchange with ocean water were to decrease or stop, a one-of-a-kind environment would be lost in southern California. The businesses that have become dependant upon the lagoon would be forced to shut down, opportunities for public access and recreation would be lost and nearly 400 acres of highly productive marine habitat would be destroyed.

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